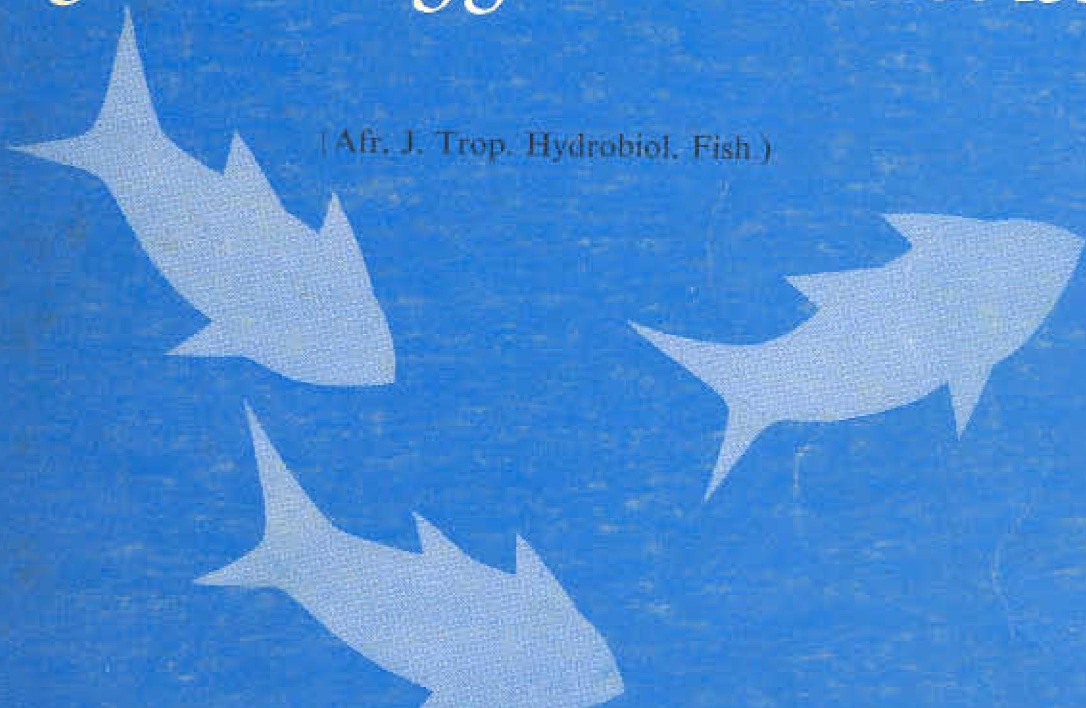
THE

AFRICAN JOURNAL OF *Tropical Hydrobiology and Fisheries*



(Afr. J. Trop. Hydrobiol. Fish.)

No. 1 Vol. 2 1972

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PUBLISHER

East African Literature Bureau, P.O. Box 30022, Nairobi, Kenya.

ISSUES

The Journal consists of one volume a year, consisting of two issues with approximately eighty pages each.

SUBSCRIPTION

Annual subscription within East Africa Sh. 35. Outside East Africa, East African Sh. 70, US $ 10.00

RELATIONSHIP BETWEEN THE WATER LEVELS AND THE FISH CATCHES IN LAKES MWERU AND MWERU WA NTIPA, ZAMBIA

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The relationships between water level and catch per effort in two Zambian lakes are compared. In the relatively stable Lake Mweru, a positive correlation exists which can be used, with certain reservations, to predict the state of the fishery two years in advance. The cause of the relationship is probably the effect of water level on the marshy and swampy breeding areas, where at least the most common species in the commercial catch (*Tilapia macrochir*) has definite limits for the depth of water in which it will breed. For Mweru wa Ntipa, a consistant definite relationship does not exist, probably because the water level and extent of the lake fluctuate widely.

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In several of the Zambian fisheries (e.g. Kafue Flats and Lake Mweru) there appears to be a correlation between water level and the landings of fish, especially cichlids, about two seasons later. If this relationship could be precisely determined, it would be a valuable tool for fisheries management, enabling prediction of the state of the fishery. The effect of water level regimes on the respective fish catches will be evaluated. As the statistical data have several shortcomings, they can be used only to indicate general trends, and the conclusions given are preliminary.

Lake Mweru has an area of 4,070 km^2, and an altitude of approximately 920 m, and is bounded along the eastern and western shores by cliffs about 50 m high. It is shallow with a generally muddy bottom, the depth increasing from 2 m at the southern end to an average of 10 m in the north, with isolated "holes" up to 27 m deep. There are two major affluent rivers; the Luapula, which drains from Lake Bangweulu and enters at the southern end; and the Kalungwishi, which drains from the highlands to the east and enters half way along the eastern shore (Fig. 1). Both affluents, especially the Luapula, have extensive marshes at their mouths. The only effluent is the Luvua River at the north-western corner. The water level is fairly stable, with a mean annual variation of 1.5 m, and an extreme of 5 m (DE KIMPE 1964).

Mweru wa Ntipa (Fig. 1) is an internal

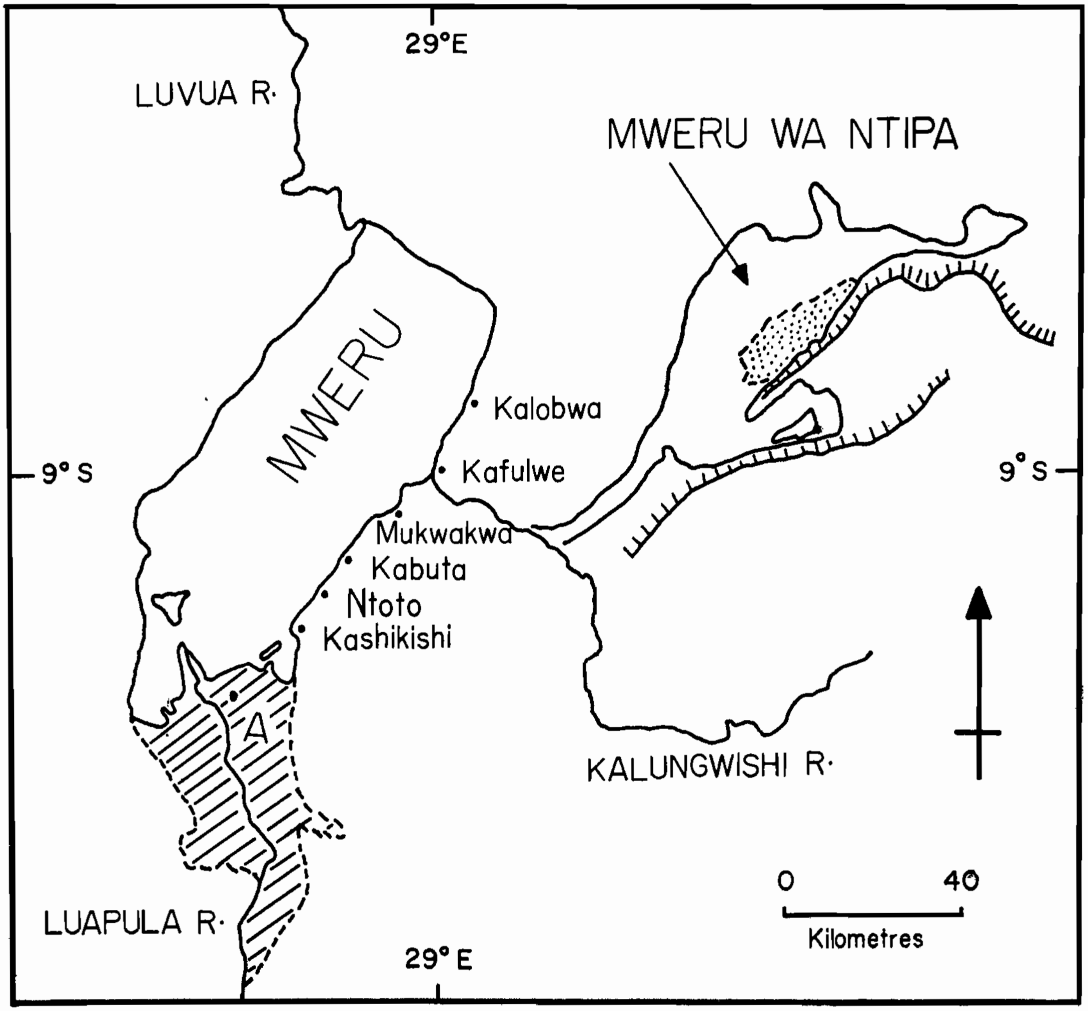

Fig 1. Map of Lake Mweru and Mweru wa Ntipa. Cross hatching shows Luapula marsh area; stippling show pre—1962 extent of Mweru wa Ntipa; indicates escarpments.

drainage system, and its area varies widely in response to water level fluctuations. Its main inlet is Mofwe Dambo, which diverts water from the Kalungwishi River during most rainy seasons (BRELSFORD 1955). Its maximum area is 1,560 km^2 although there has been no open water on at least six occasions between 1867 and 1964 (BRELSFORD 1955), and it occasionally dries out completely. The deepest and most permanent water is along the south-eastern shore, which is bordered by cliffs approximately 70 m high. The rest of the area is marshy, its extent varying with water level.

In both lakes, fluctuations in water level are correlated in time and extent with the rainfall. The rainy season lasts from October to April and averages 107 cm per annum on Mweru and 132 cm per annum on Mweru wa Ntipa (METEOROLOGICAL DEPARTMENT 1967-68).

MATERIALS AND METHODS

Fisheries statistics from 1964 to 1969 have been published for both fisheries by the Government of Zambia (GAME AND FISHERIES DEPARTMENT 1964 and CENTRAL STATISTICAL OFFICE 1965 to 1969). Pre-1964 and post-1968 data have been obtained from unpublished reports and from SOULSBY (1959, 1960). Water level data have been published by the DEPARTMENT OF WATER AFFAIRS OF ZAMBIA for 1956 to 1960. Post-1960 data have been obtained from unpublished reports.

Data on water level and catch per effort for both lakes are plotted in Figs 2 and 3, with total landings for Mweru wa Ntipa. No estimate of total landings is given for Lake Mweru as this is highly unreliable, being based on exports from the fishery plus estimated local consumption. The latter estimate has not been revised throughout the whole period of review. For Mweru wa Ntipa, the estimate of total landings is more reliable, being based on a regular gear survey and catch per effort data. At both lakes, catch per effort and species composition are measured directly at the markets.

Relationships between catch per effort and annual average water level two years previously are given in Fig. 4. The lines were fitted by the least squares method and correlations calculated by the methods of BAILEY (1959). Catch per effort was chosen as the dependant variable because it is the most reliable statistic for both fisheries, and the best one available to indicate the state of the fisheries. Catch per effort for "stationary" gill nets only was used. Data for "kutumpula" method, i.e. driving fish into the nets by beating the water, were not used because they are more liable to random variation depending on the energy of the fishermen. Regressions of catch per effort on water levels of the same year or of three years previously were less significant statistically.

RESULTS

Lake Mweru

From recorded data, the level of high water appears to follow a four- to six-year cycle. This appears to have also been the case before records started (personal communications with local residents). Fig. 2 shows that fluctuations in catch per effort tend to follow the same pattern, and that those for the southern camps, typified by Isokwe, are more extreme.

The formal correlations between water level and catch per effort averaged for seven major camps is shown in Fig. 4. Table 1 gives the average correlation coefficient and those for the seven camps individually. For most camps these are positive, and for those where it is negative, the correlation is not significant. The best fit was obtained by splitting the data into two groups and treating each group as a separate regression, viz. data relating to water levels from 1956 to 1961 (points 1 to 6 in Fig. 4), and those relating to water levels from 1962 to 1967 points 7 to 12). This division was consistent for all camps.

Mweru wa Ntipa

BRELSFORD (1955) describes the extreme variations in water level before 1954. The recorded data show a rise of 8 m between the 1961 and 1964 peaks. These variations have a great effect on the extent of open water, and for this reason Fig. 4 only shows the plot of average catch per effort for the whole area on water level. Catch per effort data are only available back to 1964 and correspond in time to the second group of Lake Mweru data. The datum points show an ordered sequence, and points

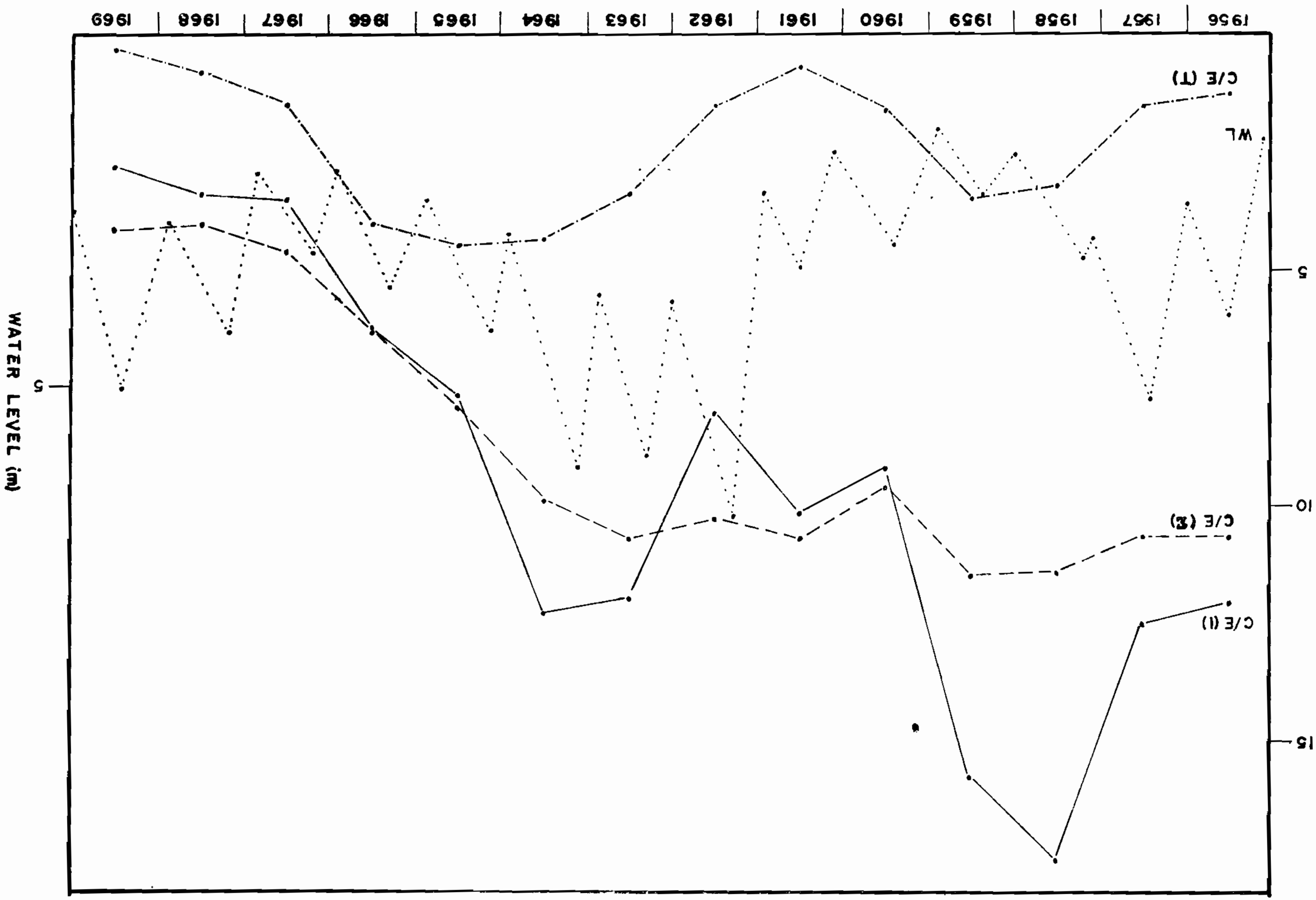

Fig 2. Lake Mweru—water level and mean annual catch per effort data. WL water level, gauge zero 915.5m amsl.; C/E (Σ) = catch per effort, all camps; C/E (I) = catch per effort, Isokwe camp; C/E (T) = catch per effort, *Tilapia macrochir*, all camps.

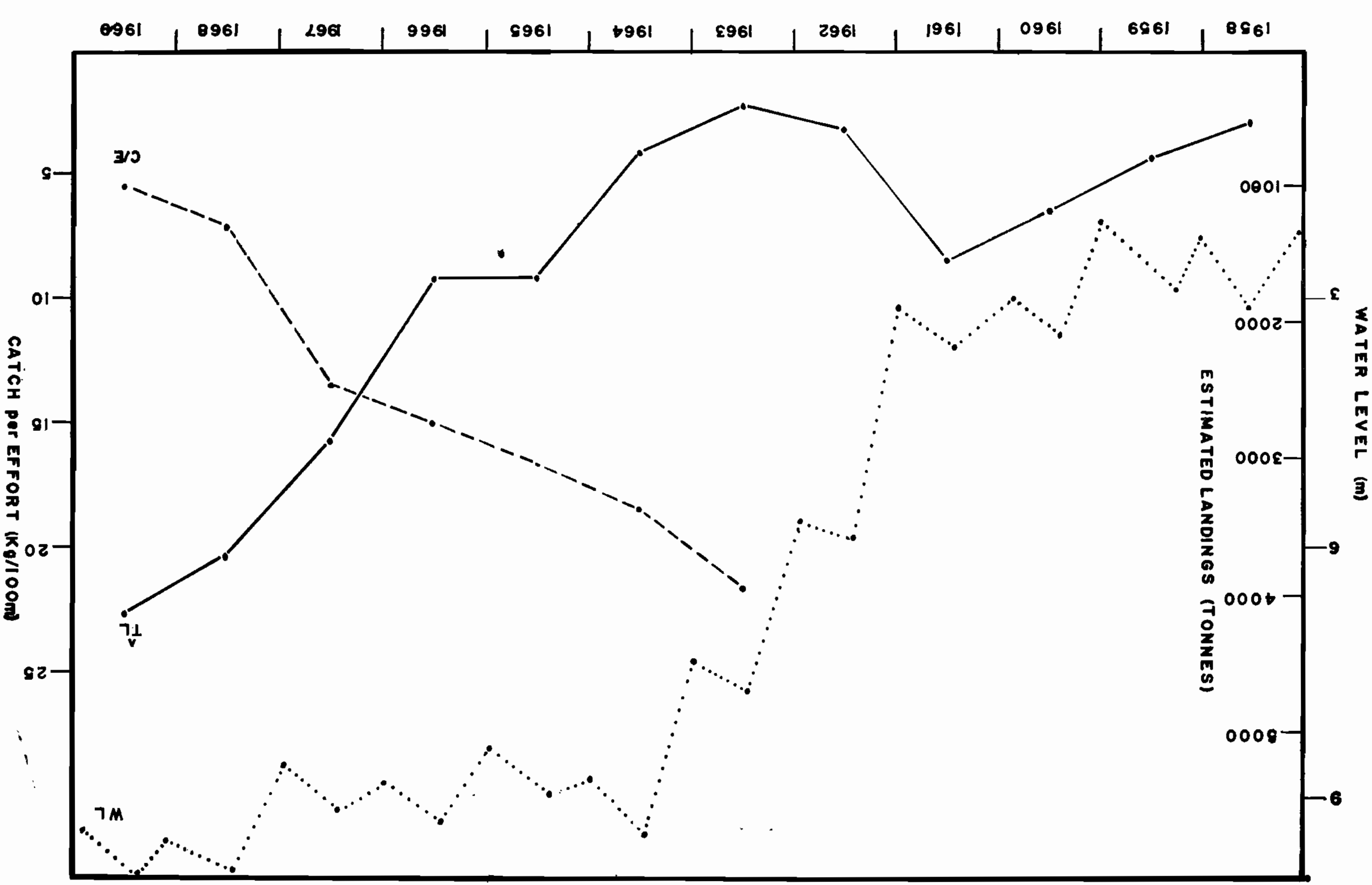

Fig 3. Mweru wa Ntipa—water level, landings and catch per effort data. WL = water level, gauge zero 919.0m amsl.; TL = estimated total landings; C/E = catch per effort, all camps.

Table 1. Correlation coefficients for regressions of catch per effort on water level two years previously.

		Degrees of freedom (n-2)	Correlation coefficient (r)	Probability (p)
Isokwe	1–6	4	0.7338	90–95%
	7–12	4	0.8556	95–98%
Kashikishi	1–6	4	0.8004	90–95%
	7–12	4	0.8598	95–98%
Ntoto	1–6	3	0.2393	90%
	7–12	4	0.8713	95–98%
Kabuta	1–6	4	0.6738	90%
	7–12	4	0.8496	95–98%
Mukwakwa	1–6	4	0.6037	90%
	7–12	4	0.7389	90–95%
Kafulwe	1–6	4	0.7742	90–95%
	7–12	4	0.9325	99%
Kalobwa	1–6	3	0.1523	90%
	7–12	4	0.7479	90–95%
Mweru wa Ntipa		4	0.8090	90–95%
L. Mweru (average)		4	0.7298	90%

1–6 refers to water level/catch per effort data from 1956/58 to 1961/63
7–12 refers to data from 1962/64 to 1967/69
Mweru na Ntipa data are from 1962/64 to 1967/69

16 to 18 represent a time during which the effort rose by 1,300%, thus invalidating any influence of water level on catch per effort. The remaining points are too few on which to draw any meaningful conclusions, and so a regression has not been drawn for this group.

DISCUSSION

Lake Mweru is relatively stable, having a fairly large outlet (the Luvua River), and the Luapula marshes to the south have a dampening effect on the major source of flood waters, by extending the period over which they are released into the lake (CAREY 1965). In 14 years the maximum annual variation in the height of the flood has been 4.5 m. Because of its relatively steep shores, variation in water level has had little effect on the area of the lake, except in the Luapula marshes. CAREY (1965) has shown that many species, especially cichlids, which between them form the bulk of the commercial catch, migrate to this area just before the start of the rains to breed. Most available data, however, refers to *Tilapia macrochir*, and so this species will be discussed. Until 1966, *T. macrochir* was the mainstay of the fishery, comprising up to 64% by numbers of the total landings (Table 2). RUWET (1962) states that in the Lufira barrage lake, where conditions approximate to those in Lake Mweru, *T. macrochir* only breeds in water between 30 cm and 150 cm deep. Calculations based on field observations show that the water depth at A (Fig. 1) is 30 cm when the gauge reads 1.71 m, and Fig. 2 shows that in several breeding seasons the water level has been at or near this critical limit. Thus in a year of relatively high water level a comparatively large area of the marshes would be flooded to a correct depth for the breeding of many species, of which (prior to 1966) *T. macrochir* was the

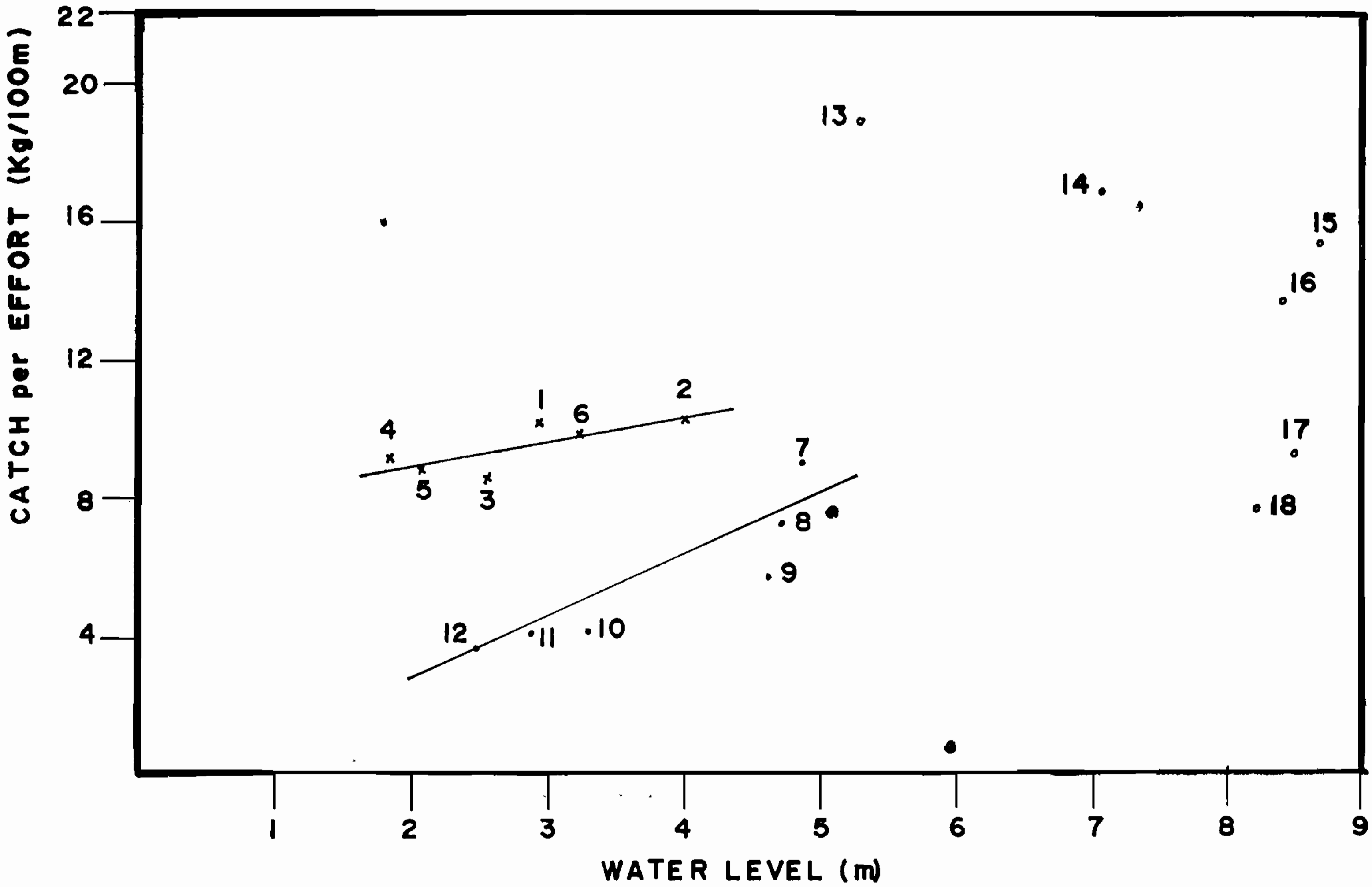

Fig 4. Regressions of catch per effort on water level two years previously. Points 1–6 refer to L. Mweru data 1958–1963; points 7–12 refer to L. Mweru data 1964–1969; points 13–18 refer to Mweru wa Ntipa data 1964–1969.

most important, thus encouraging a strong year class.

Little work on age and growth in natural waters has been done on *T. macrochir*, but DE BONT (1952) gives a mean length of 21 cm for $8\frac{1}{2}$-month-old fish reared in ponds. A figure of similar order probably applies to Lake Mweru. The mean standard length of *T. macrochir* caught in gill nets of 7.5 cm, 10.0 cm, 12.5 cm and 15.0 cm stretched measure are respectively 16.5 cm, 19.5 cm, 25.0 cm and 29.0 cm, which shows that fish about one-year-old are taken in 10 cm (stretched measure) nets. Most of the commercial *Tilapia* catch, however, is taken in 12.5 and 15 cm mesh nets, so the major exploitation is of fish about two years or older. This provides a rationale for the correlation of catch per effort with water level two years previously.

In a year of low water level, much of the marsh area would be covered with less than 30 cm of water, thus limiting breeding. CAREY (1965) states that at these times the fish breed in such shallow open water localities as Chimbofuma Bay instead. In these areas the adult fish are more easily caught during the breeding season, and the juvenile fish have no vegetative cover as protection from predators. JACKSON (1961) considers such cover important for fish less than 12 cm long in the presence of the predatory *Hydrocynus vittatus*, which is abundant in Lake Mweru, and DONNELLY (1969) also describes the importance of nursery grounds for *Tilapia* survival.

These factors can explain the general relationship of catch per effort to water level, but not the split of the data into two regressions with the rapid rise in water level (Fig. 2). This would flood much of the marsh to more than 150 cm (the minimum water depth at A in 1962 was 246 cm) and the fish would have been unable to excavate nests in the newly flooded peripheral areas with suitably deep water because of thick growths of *Cyperus papyrus, Phragmites* spp. and other vegetation (RUWET 1962). This means that no really strong brood was produced in 1962-63 to support the fishery after the strong 1956-57-58 broods had been almost fished out, and after a slight increase, the catch per effort declined below any previous level. Coincident with the declining catch per effort was a peak in effort (Fig. 5), which probably resulted in overfishing of the already weakened stock, and was responsible for the very low catch per effort values in 1968-69. Thus although in the second period the correlation between catch per effort and water level is still valid, its value is different from that of the first period.

The depth and extent of water in Mweru wa Ntipa, by contrast, are highly unstable. During the very dry periods, the fish population must be reduced to very low levels, not only because of the small extent of the water but also because of its high salinity at these times (SOULSBY 1959), so that only the more hardy species such as those of the genus *Clarias* can survive.

With sudden large changes in water level, such as between 1961 and 1963, a vast new area would become available to the fish, and presumably the salinity of the water would decrease. No data on catch per effort are available for before 1964, and so a strict comparison cannot be made with Lake Mweru. Estimated total landings, however, rose steadily during the relatively stable water conditions after the very dry period in 1954, probably as a result of gradual repopulation as conditions ameliorated, and a consequent increase in fishing activity. During the period of water level rise, the landings fell, probably because of an analogous situation to that in Lake Mweru—during the main fishing season (which coincides with the breeding season), most of the fish were in the weed-covered habitats and difficult to catch. This situation would have produced at least two strong broods, which together

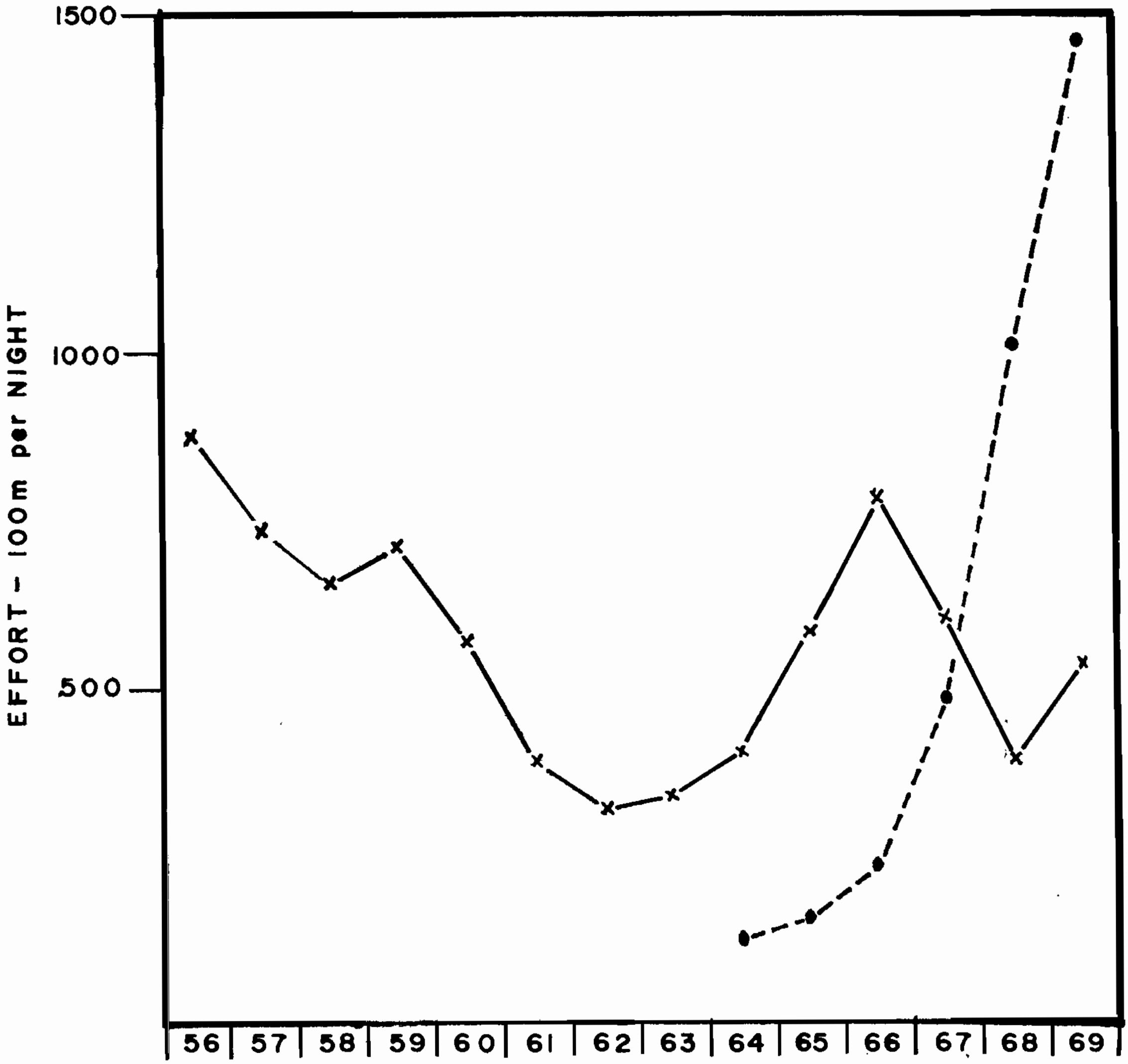

Fig 5. Fishing effort, lakes Mweru and Mweru wa Ntipa. ×——————× = Lake Mweru; 0— — — — —0 = Mweru wa Ntipa.

with an increase in effort (Fig 5) would account for the almost exponential rise in landings after 1964. This would have been helped by the continued rise in water level drowning the weed covered areas, thus increasing the catchability of adult fish. A very high percentage of the landings from Mweru wa Ntipa is *T. macrochir*, as in Lake Mweru before 1965 (Table 2).

After the water level stabilised, the catch per effort decreased steadily, which was probably due to two factors. Firstly, the configuration of the Mweru wa Ntipa basin is such that outside the pre-1962 open water area, the bottom is virtually flat until the present lake margin is reached, and is now covered with approximately 6 m of water. Thus the relatively minor water level fluctua-

Table 2. Average percentages by number of *T. macrochir* in the landings of lakes Mweru and Mweru wa Ntipa

Mweru		Mweru		Mweru wa Ntipa
1956	11.6	1963	32.1	—
1957	13.5	1964	43.7	98.45
1958	29.1	1965	53.4	84.30
1959	35.3	1966	63.9	82.30
1960	19.6	1967	32.8	82.50
1961	7.2	1968	9.8	74.60
1962	15.4	1969	5.4	78.46

tions since 1964 would not have reduced the water depth in this area to the range suitable for highly successful breeding, and thus no really strong year classes were produced since the period of intermediate water level between 1962 and 1964. Secondly, the increase in effort between 1965 and 1969 possibly reduced the stock at a faster rate than it was being replaced by the subsequent weaker year classes.

RESUME

1. Dans un lac caractérisé par un régime hydrologique stable, tel que le lac Moero, dont la pêche est basée largement sur des espèces qui se reproduisent dans les marais, le rapport entre le niveau de l'eau et la prise par unité d'effort fournit à la gestion de la pêcherie une hypothèse prophétique de la valeur potentielle.
2. Plusieurs espèces d'une importance commerciale se reproduisent dans les marais autour de l'embouchure de la Luapula, et on sait que pour le *Tilapia macrochir* il y a parmi les profondeurs de l'eau un rayon limité dans lequel la reproduction s'effectue.
3. Cette zone est, en pratique, la seule dans laquelle les variations du niveau de l'eau agissent d'une manière significative, sur l'étendue des terrains de reproduction appropriés.
4. Il existe une correlation entre le niveau de l'eau et la prise par unité d'effort 2 années plus tard, au moment où cette classe d'âge est recrutée par la pêche. Les données sur le lac Moero se divisent en ceux classes; pour chacune on dispose d'une regression d'une signification statistique. Elle est le résultat d'une longue période mal adaptée à la fraie, suivie par une pointe d'effort qui réduisait probablement le stock déjà affaibli.
   Comme le rapport général reste encore valable, les valeurs pour la prise par unité d'effort sont plus faibles.
5. Au fond l'hypothèse pour le lac Moero-wa-ntipa est pareille, mais pour 2 raisons on ne peut pas prévoir une prédiction valable:
   (a) l'effort de pêche change a beaucoup pendant la période traitéee.
   (b) le bassin du Moero-wa-ntipa comprend 2 parties principales: (i) la zone avec une correspondance appropimative à la superficie des eaux libres avant 1962, caractérisée actuellement par une profondeur entre 7 et 9 m, et (ii) la zone restante qui était, avant 1962, soit sèche, soit bourrée de papyrus mais couverte à présent jusqu'a la rive d'une couche d'eau de 6 m environ. Il en résulte que les conditions les plus favorables pour la reproduction se présentent seulement un peu après la montée des eaux hors de la zone profonde, et il n'y existe pas une zone flexible de marécage pendant que le niveau de l'eau se maintient à la hauteur actuelle. Aussi peu après que le lac occupait sa superficie maximale, les petites variations subséquentes du niveau de l'eau n'agissaient pas d'une manière

significative sur la reproduction des poissons, et par conséquent n'agissaient plus sur la pêche.

CONCLUSIONS AND SUMMARY

1. For a hydrologically stable lake, such as Mweru, with a fishery depending largely on marsh breeding species, the relationship between water level and catch per effort provides a predictive hypothesis of potential value to fisheries management.
2. Many commercially important species breed in the marshes around the mouth of the Luapula, and T, *macrochir* is known to have a limited range of water depth in which it will breed.
3. This area is virtually the only one in which water level fluctuations significantly affect the extent of suitable breeding grounds.
4. A correlation exists between the water level and the catch per effort two years later, when that year class is recruited to the fishery. The data from Lake Mweru fall into two groups, for which statistically significant regressions can be obtained. This is a result of an extended period of unsuitable breeding conditions followed by a peak in effort, which probably reduced an already weakened stock, so that while the general relationship is still valid, the values are lower for catch per effort.
5. The rationale for Mweru wa Ntipa is basically similar, but a valid prediction cannot be obtained for two reasons:
   (*a*) The fishing effort during the period under review changed dramatically.
   (*b*) The Mweru wa Ntipa basin has two main parts; the area roughly corresponding to the pre-1962 extent of open water, which at the present time has a depth of 7 to 9 m, and the remaining area which before 1962 was either dry or choked with papyrus, but now is covered with approximately 6 m of water almost to the edges. This means that highly suitable conditions for fish breeding only occur soon after the water breaks out of the deeper area, and that no "elastic" marsh area exists when the water level is at its present height. Thus soon after the lake occupied its maximum extent, relatively minor subsequent variations in water level had no significant effect on fish breeding and consequently none on the fishery.

ACKNOWLEDGEMENTS—I am grateful to Dr. R. Kendall and Dr. R. Armstrong for their advice concerning this work.

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